A STUDY OF RESISTANCE-CAPACITANCE TUNED VARIABLE FREQUENCY OSCILLATOR

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AMIYA KUMAR CHATTERJEE

A.M.E.E., College of Engineering & Technology, Jadavpur, India, 1935
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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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A STUDY OF RESISTANCE-CAPACITANCE TUNED VARIABLE FREQUENCY OSCILLATOR

The use of resistance-capacitance tuned variable frequency oscillator has become quite common as present day laboratory equipment for various measurements. Previous studies of these types of oscillators are mostly descriptive in nature. An attempt has been made in this work to give an analytical solution of problems such as, conditions of oscillation, amplitude of steady state oscillation, selectivity, distortion, etc. The circuits studied consist of a two stage resistance-capacitance coupled amplifier the output of which is fed back to the input through a suitable feedback network.

To reduce the distortion in the amplifier, it is essential that the amplifier be, as nearly as possible, linear in its operation. H. S. Black[1] has shown that by using negative feedback both noise and distortion could be reduced by a factor $(1-\mu\beta)$, where μ is the gain of the amplifier without feedback, and β is the feedback factor. Black's theory on reduction of distortion by feedback neglects the effect of secondary distortion. Assuming that the anode current is given by a power series expansion in grid voltage and then neglecting all terms higher than the square term, an analytical solution has been obtained for the case of current feedback. It has been shown that as long as the output voltage is small, the neglecting of secondary distortion makes hardly any difference in the result; whereas for higher output voltages the error introduced may be quite serious. For a 6J6 tube operated at plate voltage of 160 volts, grid voltage of -4 volts and load resistance of 51, 8 00 ohms, it is shown that with current feedback obtained through a cathode resistance of 1000 ohms the error introduced due to neglecting the secondary distortion is negligible when the grid swing is 1 volt (R.M.S). For a grid swing of 2 volts (R.M.S) the error is about 2 %.

A graphical method of finding the non-linear distortion has

been developed. In this method the feedback network is conceived of as a component of the tube. A family of characteristic curves is constructed from the static characteristics of the normal tube, so as to include the effect of a particular feedback condition. This family of equivalent characteristics are then used to find the harmonic distortion without any further consideration of feedback. In case of voltage feedback, the transconductance of the equivalent tube remains unchanged while the plate resistance and the amplification factor are both reduced by the same factor $1/(1+\mu\beta)$. For current feedback, the amplification factor remains unchanged but the plate resistance is increased by $(1+\beta g_m)$ and the transconductance is decreased by $1/(1+\beta g_m)$.

The conditions of oscillation have been obtained using the method outlined by Bode.[2] The circuit selected consists of a two stage R-C coupled amplifier, the output of which is fed back to the input through a R-C zero phase shift network. The frequency of oscillation is determined by this feedback network. It has been shown that such a network is equivalent to a parallel circuit consisting of a condenser c_2 in one branch, a resistance r_2 in the second branch and a negative resistance ρ and a negative capacity c' in series in the third branch. Equating the circuit determinant to zero, the roots of $p = \alpha + j\omega$ are obtained. From this the conditions of oscillation are obtained as summarized below:

1. Conditions for sinusoidal oscillation: if ω is real.

i.e., if $|\rho| > \frac{r_2}{c'}\left\{ c_2 - c' \pm 2\sqrt{-c_2c'} \right\}$

(a) If $|\rho| > r_2\left(1+\frac{c_2}{c'}\right)$,

the amplitude of oscillation decreases with time.

(b) If $|\rho| = r_2\left(1+\frac{c_2}{c'}\right)$,

the amplitude of oscillation is contsant.

(c) If $|\rho| < r_2\left(1 + \frac{c_2}{c'}\right)$,

the amplitude of oscillation increases with time.

2. The current is exponential in form if ω is imaginary

i.e., if $|\rho| < \frac{r_2}{c'}\left\{ c_2 - c' \pm 2\sqrt{-c_2c'} \right\}$

(a) If $|\rho| \leq r_2\left(1 + \frac{c_2}{c'}\right)$,

there is sustained non-sinusoidal oscillation.

(b) If $|\rho| > r_2\left(1 + \frac{c_2}{c'}\right)$,

the current is an exponential pulse.

An appropriate chart showing above has been developed following the method of Reich.[5]

In the analysis of the amplitude of oscillation it has been assumed that the amplifier is linear in operation and that the amplitude of oscillation is controlled by a thermal element in the form of a tungsten filament lamp in the cathode circuit of the first tube. If the lamp is operated at a voltage lower than the rated value, the resistance voltage characteristic can be approximated by a straight line. The technique used in finding the amplitude of oscillation consists of breaking the circuit between the coupling condenser and the grid of the second tube of the amplifier and connecting an alternating voltage source of variable voltage and frequency across the input of this tube. An expression for the output voltage V_1 of the first stage, corresponding to a voltage e_{g2} of the external generator, is then obtained. If self excitation is to exist when the generator is disconnected and the original connection is restored, V_1 and e_{g2} should become equal in magnitude and in phase. Using this condition and replacing the resistance of the thermal element by a constant cold resistance plus a constant rate of rise of resistance per effective votage times the effective voltage

across the lamp, an expression for the steady state effective voltage across the lamp has been obtained. The frequency of oscillation is given by

$$\omega = 1/rc$$

where r and c are the resistance and capacity of the frequency determining cirruit respectively. The frequency is varied by using a variable air condenser for c.

For a simple R-C zero phase shift network, as the feedback circuit, the variation of the feedback factor β with frequency resembles the impedance characteristic of a parallel resonant circuit. A factor Q has been defined by comparison with the parallel resonant circuit. It has been shown that Q varies from 0.2 to 0.45 for values of circuit components that are of practical interest. Using a Wein bridge as the β network, it has been shown that Q under working condition is given by

$$Q = Q_o \mu_1 \mu_2 \beta_o$$

where Q_o corresponds to the figure of merit of the frequency determining circuit alone, and μ_1 and μ_2 are the gains of the first and second stages respectively. The value of Q is thus increased in operation by a factor $\mu_1 \mu_2 \beta_o$. It has further been shown that by using a double triode for the first stage, a further increase in the value of Q may be obtained. The improvment in the slope of the phase angle of β during operation is also shown. It will be recalled that the slope of the phase angle at the operating point should be large, in order to obtain high frequency stability and low harmonic content. Using high μ tube for the first stage it is possible to obtain a value of Q greater than 150.

An oscillator was built up in the laboartory and the following conclusions have been reached from the experimental results:

1. The total harmonic content of the oscillator for all loads above 1000 ohms is less than 0.4%.

2. The warming up frequency drift for the first 15 minutes

after the oscillator is switched on does not exceed 0.1%.

3. The frequency drift after the initial warming up period is limited to 0.08%.
4. The output voltage of the oscillator is practically constant between the maximum and minimum positions of the ganged condenser for each switch position.
5. The measured and theoretical values of the steady state amplitude of oscillation check fairly close.
6. The output impedance is low and therefore is not critical for loads above 1000 ohms.

A detailed discussion of the methods of measurement is given in the original thesis.

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VITA

The author was born at Feni, Bengal, India on August 31, 1913. He matriculated from Agartala U. K. Academy, Tipperah State, India in 1929; passed the Intermediate examination in science of the Calcutta University in 1931 from Comilla Victoria College and graduated in electrical engineering from the College of Engineering and Technology, Jadavpur, Bengal, India in 1935 with first class honors. For three years after graduation (1935-38) he was an instructor at the College of Engineering and Technology, Jadavpur. He received a post-graduate training at Messrs. Ferranti Ltd., England, for one year during 1938-39. Coming back home, he worked for about a year at the British India Electric Construction Co. Ltd., in Calcutta. In 1941, he came back to his "Alma Mater," Jadavpur College of Engineering and Technology, as a member of the teaching staff.

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